Survey of Red Sea Urchin Populations In the Area of Campania Island, British Columbia, 2004

M. Atkins, A. Campbell, W. C. Hajas, and D. Tzotzos

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

2006

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2750

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

106-07187/

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2750

2006

SURVEY OF RED SEA URCHIN POPULATIONS IN THE AREA OF CAMPANIA ISLAND, BRITISH COLUMBIA, 2004

by

M. Atkins[1], A. Campbell, W. C. Hajas, and D. Tzotzos

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

[1]Pacific Urchin Harvesters Association
902 – 4th Street,
New Westminster, British Columbia
V3L 2W6

© Her Majesty the Queen in Right of Canada, 2006

Cat. No. Fs 97-4 /2750E ISSN 0706-6473

Correct citation for this publication:

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in the area of Campania Island, British Columbia, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2750: iii + 21 p.

ABSTRACT

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in the area of Campania Island, British Columbia, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2750: iii + 21 p.

A survey of red sea urchin populations was conducted in the area of Campania Island, Pacific Fisheries Management (PFM) sub-area 6-10, during August, 2004. A total of 68 transects were surveyed by SCUBA divers, and 3385 red sea urchins were measured. The density of red sea urchins of all sizes and of legal size (≥90 mm test diameter, TD) was 3.08/m^2 and 1.65/m^2, respectively. There was no significant difference in estimated mean density (number/m^2) or biomass (g/m^2) between red sea urchins found inside (50 transects) and outside (18 transects) previously fished commercial bed areas. Overall, 12.3% of all red urchins measured were ≤50mm TD whereas 54.0% were of legal size for the commercial fishery.

RÉSUMÉ

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in the area of Campania Island, British Columbia, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2750: iii + 21 p.

Un relevé des populations d'oursins rouges a été réalisé en août 2004 dans la région de l'île Campania (sous-secteur 6-10 de gestion des pêches du Pacifique). Au total, 68 transects ont été couverts par des plongeurs autonomes, qui ont mesuré 3385 oursins rouges. La densité des oursins rouges de toutes tailles et de taille réglementaire (≥90 mm de diamètre du test, DT) était respectivement de 3,08/m^2 et 1,65/m^2. On n'a pas noté de différences significatives dans la densité moyenne estimée (nombre/m^2) ni dans la biomasse (g/m^2) entre les oursins rouges observés à l'intérieur (50 transects) et à l'extérieur (18 transects) de gisements auparavant exploités par la pêche commerciale. Dans l'ensemble, 12,3 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 54,0 % avaient la taille réglementaire pour la pêche commerciale.

INTRODUCTION

Red sea urchin (*Strongylocentrotus franciscanus*) distribution along the Pacific Coast of North America ranges from the southern tip of Baja California to Alaska (Kato and Schroeter 1985). Red sea urchins are found throughout shallow rocky subtidal habitats of British Columbia (Bernard 1977; Campbell and Harbo 1991). Sea urchins are commercially harvested for their gonads (roe), which are sold mainly in Japan. Coastal First Nations communities harvest sea urchins as part of their traditional food, social and ceremonial fisheries. The commercial red sea urchin fishery began in British Columbia (BC) in the early 1970's and the total landed value for the 2003-2004 season was $7.7 million (Juanita Rogers, pers. comm.), making the harvest of red sea urchins a valuable shellfish fishery in BC.

The commercial red sea urchin fishery history and management were described in Campbell and Harbo (1991), and Campbell et al. (1999a). Currently, several approaches are used in the management of the red sea urchin fishery, including: a minimum commercial harvest size of 90 mm test diameter (TD); area licensing; individual vessel quotas; area quotas; and limited licence entry. Quota calculations are based on estimates of urchin density from field surveys, and estimates of urchin bed areas. Density estimates are therefore essential to the assessment and management of the sea urchin fishery.

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Breen et al. (1976, 1978), Adkins et al. (1981) and Sloan et al. (1987). Since 1993, red sea urchin population surveys have been conducted as a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations, and Fisheries and Oceans Canada (DFO) (Jamieson et al. 1998a-d; Bureau et al. 2000a-d; Tzotzos et al. 2003a-d, 2006; Atkins et al. 2006a-g).

Fishery managers requested that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. The Campania Island area [Pacific Fishery Management (PFM) sub-area 6-10] (Figure 1), was selected for survey through discussion between PUHA and DFO. The objective of this paper is to present detailed survey results and to estimate the density and biomass of red sea urchins within and outside of commercially fished beds, for PFM sub-area 6-10.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in PFM sub-area 6-10. Transect locations were selected and plotted on a marine chart prior to the survey to avoid bias in the field.

Transects were systematically placed along the shoreline with a random starting point. The ArcView GIS system was used to measure the shoreline length (SL) of the

survey area, including islands. The position of the first transect was determined randomly, and subsequent transects were then spaced evenly along the shoreline. Areas of unsuitable red sea urchin habitat (eg. sand and mud substrates) were excluded from the survey area. Since variation in urchin density was unlikely to match the spacing of the transects, the systematic sample was treated as a random sample of transects (Jamieson and Schwarz 1998).

Survey Logistics

Due to diver injury the survey was completed in two trips; the first conducted from August 8-12, 2004, on the "Twin Starrs", and the second conducted from August 27-September 1, 2004, on the "Westport 1"; both are commercial red sea urchin fishing vessels. A crew of four people, consisting of three divers, one of which was a biologist, and the other two commercial red sea urchin harvesters, and a boat tender, was used for both trips.

Dive Survey Methods

In the field, location of transects were determined from geographical references on the shoreline, and GPS. Exposure to wave action/current was recorded, for each transect, as one of nine codes: 0 = extreme shelter, 1 = minimal sea movement, 2 = well sheltered, 3 = occasional current, 4 = moderate exposure, 5 = strong tidal flow, 6 = high tide surge only, 7 = ground swell normal, 8 = high exposure. Leadline transects were laid perpendicular to shore from the boat, with a float attached to the deep end of each transect. Transects were laid out from shallow water to a depth of 15m (not corrected for tide), so transect length was dependent on the slope of the substrate and tide height. A two-diver team surveyed each transect from deep to shallow, one diver measured urchins while the other recorded data. A one meter squared (1 m^2) quadrat was placed on the bottom beside the transect and the test diameter (TD) of each red urchin present was measured, with callipers, to the nearest millimeter. If urchins could not be measured because they were inaccessible or broken/lost they were still counted, therefore the count of urchins in a quadrat may be higher than the number measured. The depth, substrate type, types of algae (and percent cover), shell length of abalone (*Haliotis kamtschatkana*), and TD of green (*S. droebachiensis*) and purple (*S. purpuratus*) sea urchins present in each quadrat were also recorded. The quadrat was then moved 2 m forward along the transect and the process was repeated, so that every second meter of the transect was surveyed. In cases where no urchins were found at the deep end of transects, observations of depth, substrate and algae were recorded only every 20 m to minimize dive time. In such cases, skipped quadrats were assigned zero values for urchin counts before data were analysed. Once urchins were encountered, sampling was conducted every 2 m until the intertidal zone or the surface was reached.

DATA ANALYSIS

Habitat

Depth Categories

Gauge depths recorded by divers were corrected to depth below Chart Datum by subtracting tide height from the observed depths. Tide heights from the closest tide station were used to correct depths. The depth (m) for each quadrat was assigned to one of seven depth ranges: 1= <0.0m; 2= 0.0 - <2.5m; 3= 2.5 - <5.0m; 4= 5.0 - <7.5m; 5= 7.5 - <10.0m; 6= 10.0 -<12.5m; and 7= ≥12.5m.

Substrate

The divers recorded the dominant substrates (up to three) within each quadrat using one of nine generic codes: 1=smooth bedrock; 2=bedrock with crevices; 3=boulders, >30cm; 4=cobble, between 7.5cm and 30cm; 5=gravel, between 2cm and 7.5cm; 6=pea gravel, between 0.25-2cm; 7=sand; 8=shell; and 9=mud. For the analysis, the nine substrate codes were grouped into three main dominant categories: 1=rock (codes 1-5); 2=sand/shell (codes 6-8); and 3=mud (code 9). Each quadrat was assigned a dominant substrate code in order to determine the average percent of each dominant substrate.

Algae

Algal species were assigned to one of four categories based on growth characteristics: canopy (taller than 2m), understorey (30cm to 2m), turf (<30cm), and encrusting. The percent cover of algae in each category, for each quadrat, was calculated as the sum of the individual species' percent cover. Mean percent cover, by growth category, for each depth category was then calculated by averaging the quadrat percent covers over the depth category.

Estimation of Density and Biomass

Density and biomass estimates were calculated from transects that were located inside commercially harvested red sea urchin beds, for transects located outside of the harvested beds, and for all transects combined. Commercially harvested beds were defined as areas where commercial harvesting occurred between 1997 and 2000; therefore, areas defined as outside beds may have had fishing events prior to 1997 and/or after 2000. The process involved in defining the commercially harvested urchin beds was described by Campbell et al. (2001).

Density and biomass were estimated for red urchins in three size groups: a) all sizes, b) small urchins <50 mm TD, and c) urchins of legal size for the commercial fishery (≥90 mm TD). Estimates of mean density and biomass were calculated using the equations below.

Density estimates (d_{ts}) in number of red sea urchins per meter squared for each transect (t) and size group (s) were calculated as:

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}} \tag{1}$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mts} is the number of red urchins measured in size group s on transect t, N_{mt} is the total number of red urchins measured on transect t, and a_t is the surface area of all quadrats surveyed on the transect t. Here a_t is equal to the number of all quadrats surveyed on the transect since each quadrat had a surface area of 1 m^2.

Overall mean density ($\overline{d}_s$) for urchins of size group s, was estimated as a weighted mean of transect densities:

$$\overline{d}_s = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t} \tag{2}$$

where L_t is the length of transect t (Campbell et al. 1999b).

The standard error (s_d) of estimated mean density was calculated as:

$$s_d = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_{ts} * L_t - \overline{d}_s * L_t)^2}{n * (n-1) * \overline{L}^2}} \tag{3}$$

where n is the number of transects surveyed, T is the total possible number of transects that can be sampled and mean transect length ($\overline{L}$) was calculated as:

$$\overline{L} = \frac{\sum_t L_t}{n} \qquad \text{(Campbell et al. 1999b)} \tag{4}$$

The expression $\sqrt{(1-(n/T))}$ was approximately equal to 1 since n was much smaller than T.

To calculate biomass, the weight of each red urchin measured was calculated using the relationship between urchin weight (W) in grams and test diameter (TD) in millimetres (Campbell et al. 1999b, 2000).

$$W = 0.0012659 * TD^{2.7068} \quad n = 167,\ r^2 = 0.960 \tag{5}$$

Biomass density (b_{ts} in grams per meter squared) of urchins of size group s, on a transect t, was estimated using a simplified form of the formula used in previous papers (Campbell et al. 2000). The formula was modified by Campbell et al. (1999b) to simplify computations:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t} \qquad (6)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mt} is the total number of red urchins measured on transect t, ΣW_{ts} is the sum of the weights of red urchins measured in size group s on transect t and a_t is the surface area of quadrats surveyed on the transect t.

Overall estimated mean biomass ($\overline{b_s}$) per surface area (grams per meter squared) was calculated as a weighted mean of transect biomass:

$$\overline{b_s} = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t} \qquad \text{(Campbell et al. 1999b)} \qquad (7)$$

The standard error of estimated mean biomass was calculated using the same formula used for standard errors of density, but d_{ts} and $\overline{d_s}$ were substituted for b_{ts} and $\overline{b_s}$, respectively. The biomass estimate was converted into quota recommendations for management purposes by Campbell et al. (2001).

A Kruskal Wallace Analysis (Systat 10) was used to compare red urchin densities between inside and outside of commercial beds.

Density and biomass estimates were also generated by depth.

Recruitment

Estimates of recruitment (R_T) of red sea urchin populations in BC have generally been expressed as a percentage of the total number of red sea urchins measured that were ≤50 mm TD (Adkins et al. 1981; Breen et al. 1976, 1978; Jamieson et al. 1998b, 1998c, 1998d; Sloan et al. 1987). For comparison purposes, the same method was used here. Recruitment was also calculated as a percentage of the total number of sub-legal red sea urchins (<90 mm TD) that were ≤50 mm TD (R_S). This method may provide a less biased measure of recruitment in areas where a commercial fishery has taken place, since the numbers of sea urchins ≥90 mm TD may be reduced due to the harvest (Tegner and Dayton 1981).

RESULTS

SURVEY LOGISTICS

In total, 68 transects were surveyed during 10 dive days (Table 1, Figure 1). A total of 3485 red sea urchins were counted and 3385 were measured for TD in 1126 quadrats along the 68 transects. The total transect length surveyed was 2186 m, for an

average transect length of 32 m. Fifty transects (74%) were located on commercial red sea urchin beds recorded from 1997 to 2000 (Table 1).

SUBSTRATE AND HABITAT

All transects surveyed had a moderate or high exposure (Table 1). Of the total (1126) quadrats sampled, 74% had rock, and 26% had sand/shell as the primary substrate. Of the 3485 red sea urchins counted, 89% were observed between 0.0 m and 7.5 m.

The highest percent cover of canopy, understory and turf algae was found <0m chart datum; understorey and encrusting algae were consistently encountered at all depths surveyed (Table 2).

SIZE FREQUENCY DISTRIBUTION

The overall mean TD of red sea urchins measured was 88.7 mm TD (Table 3, Figure 2). The smallest and largest red urchins measured were 6 mm and 168 mm TD, respectively. The overall percent of legal-sized red sea urchins (≥90 mm TD) was 54.0%, whereas the percentage of urchins ≤50 mm TD (R_T) was 12.3%. Of the sublegal urchins, the proportion that was ≤50 mm TD (R_S) was 26.7% (Table 3).

The mean TD of red sea urchins found inside commercial bed areas was 87.3mm (n=2719); 52% were of legal size. Outside bed areas, the mean TD was 94.3mm (n=666) and 64% were of legal size (Table 3).

DENSITY AND BIOMASS ESTIMATES

For all transects combined, the estimated mean density and biomass for red sea urchins of all sizes was 3.08 /m^2 and 905.7 g/m^2, respectively, and 1.65 /m^2 and 743.7 g/m^2 for legal-sized red urchins (Table 4). Although differences in density between in and out of bed areas were observed, the differences were not significant (Table 5).

The highest mean density and biomass of red sea urchins of any size category were observed in the 0.0-2.5m depth range; densities were highest in that depth range for red urchins found both inside and outside of commercial bed areas (Tables 6 and 7), although no statistical tests were performed to confirm significance.

DISCUSSION

The mean TD of red sea urchins found inside commercial bed areas (87.3 mm) was smaller than red sea urchins found outside bed areas (94.3 mm). This may be an indication of harvesting pressure in PFM sub-area 6-10, higher recruitment inside commercial bed areas than outside, or may simply be an artefact of a small sample size.

Recruitment was defined here as the percent of the total red sea urchin population that was ≤50 mm TD (R_T). Red sea urchin populations often have low recruitment (Bernard 1977; Sloan et al. 1987); however, comparing recent survey results (2000-2004) suggests that recruitment in the central and north coast has been higher than that in the south coast of BC in recent years. The level of recruitment at Campania (12.3%) was lower than that observed in a 1997 survey at Banks Island (16.4%) (Bureau et al. 2000d), and was less than half that observed in Fitz Hugh Sound (30.7%) (Atkins et al. 2006f) and Laredo Channel (31.7%) (Tzotzos et al. 2003c). It was however higher than a recent survey in the Dundas Group (5.6%) (Atkins et al. 2006c). Numerous factors could influence recruitment at any given area including physical and oceanographic influences, predation on larvae and juveniles, and interactions between juveniles and adults (Kalvass 1992; Sloan et al. 1987). A higher proportion of transects were laid on beds in the Campania Island survey than on other surveys. If removal of adults though harvesting negatively affects recruitment, a lower overall recruitment rate could be expected on surveys where a higher proportion of transects fall on beds where commercial harvest has taken place.

The overall density and biomass estimates of red sea urchins during the current survey (3.08/m^2 and 905.7 g/m^2) were higher than recent surveys at Banks Island (2.23/m^2 and 325.9 g/m^2) (Bureau et al. 2000d) and Beaver Pass (1.10/m^2 and 423.87 g/m^2) (Atkins et al. 2006b) on the north coast; Laredo Channel (1.33/m^2 and 325.9 g/m^2) (Tzotzos et al. 2003c) and Fitz Hugh Sound (1.12/m^2 and 274.63 g/m^2) (Atkins et al. 2006f) on the central coast; and recent surveys in the south coast, around Vancouver Island, the highest density being in Barkley Sound (2.53/m^2 and 756.91 g/m^2) (Atkins et al. 2006a).

The highest density and biomass estimates were found at the depth range between 0 and 2.5m, which could have been due to the depth where their food, algae and algal drift were most abundant combined with being the shallowest depths generally tolerated by red sea urchins.

ACKNOWLEDGEMENTS

We thank Bob Hegedus, James Mahon, and Flavius Picui for conducting the dive survey; James Newton, for boat tending; the PUHA for providing financial and logistical support for the survey; Leslie Barton for preparing figure 1, and Dominique Bureau for reviewing this paper.

REFERENCES

Adkins, B.E., Harbo, R.M., and Breen, P.A. 1981. A survey of commercial sea urchin (*Strongylocentrotus franciscanus*) populations in the Gulf Islands, November 1980. Can. Manuscr. Rep. Fish. Aquat. Sci. 1618: 41 p.

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006a. Survey of red sea urchin populations in Barkley Sound, British Columbia, 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2752: 33 p.

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006b. Survey of red sea urchin populations in Beaver Pass and Freeman Pass, British Columbia, 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2754: 25 p.

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006c. Survey of red sea urchin populations in the Dundas Group, British Columbia, 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2751: 27 p.

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006d. Survey of red sea urchin populations near Robson Bight, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2755: 23 p.

Atkins, M., Tzotzos, D., Hajas, W.C., and Campbell, A. 2006e. Survey of red sea urchin populations off Campbell River, British Columbia, 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2753: 25 p.

Atkins, M., Tzotzos, D., Campbell, A., and Hajas, W.C.. 2006f. Survey of red sea urchin populations in Fitz Hugh Sound, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2756: 25 p.

Atkins, M., Tzotzos, D., Hajas, W.C., and Campbell, A. 2006g. Survey of red sea urchin populations in Queen Charlotte Strait, British Columbia, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2749: 25 p.

Bernard, F.R. 1977. Fishery and reproductive cycle of the red sea urchin, *Strongylocentrotus franciscanus*, in British Columbia. J. Fish. Res. Board Can. 34: 604-610.

Breen, P.A., Miller, D.C., and Adkins, B.E. 1976. An examination of harvested sea urchin populations in the Tofino area. Fish. Res. Board Can. Manuscr. Rep. 1401: 23 p.

Breen, P.A., Adkins, B.E., and Miller, D.C. 1978. Recovery rate in three exploited red sea urchin populations from 1972 to 1977. Fish. Mar. Serv. Manuscr. Rep. 1446: 27 p.

Bureau, D., Campbell, A., and Hajas, W.C. 2000a. Survey of red sea urchin populations near Comox, Denman Island and Hornby Island, British Columbia, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2546: 17 p.

Bureau, D., Campbell, A., and Hajas, W.C. 2000b. Survey of red sea urchin populations in the Kelsey Bay Area, Johnstone Strait, British Columbia, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2542: 19 p.

Bureau, D., Campbell, A., Hajas, W.C., and Ayers, C.A. 2000c. Survey of red sea urchin populations in the Gulf Islands, Strait of Georgia, British Columbia, 1998 and 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2552: 29 p.

Bureau, D., Campbell, A., and Hajas, W.C. 2000d. Survey of red sea urchin populations in the Larsen Harbour and Kingkown Inlet areas, Banks Island, British Columbia, 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2551: 19 p.

Campbell, A., and Harbo, R.M. 1991. The sea urchin fisheries in British Columbia, Canada, p.191-199. *In:* T. Yanagisawa, I. Yasumasu, C. Oguro, N. Suzuki, T. Motokawa, [eds.]. Biology of echinodermata. A. A. Balkema, Rotterdam.

Campbell, A., Boutillier, J., and Rogers, J. 1999a. Discussion on a precautionary approach for management of the red sea urchin fishery in British Columbia. Can. Stock Assessment Secretariat Res. Doc. 99/094: 49 p.

Campbell, A., Hajas, W.C., and Bureau, D. 1999b. Quota options for the red sea urchin fishery in British Columbia for fishing season 2000/2001. Can. Stock Assessment Secretariat Res. Doc. 99/201: 67 p.

Campbell, A., Bureau, D., and Brouwer, D. 2000. Quota estimates for the 1998 red sea urchin fishery in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2516: 31 p.

Campbell, A., Tzotzos, D., Hajas, W.C., and Barton, L.L. 2001. Quota options for the red sea urchin fishery in British Columbia for fishing season 2002/2003. Can. Stock Assessment Secretariat Res. Doc. 2001/141.

Jamieson, G.S., Cripps, K., Gijssen, M., Greba, L., Jones, R., Martel, G., Sandoval, W., Schwarz, C.J., Taylor, C., and Routledge, R. 1998a. Reanalyses of the 1993 red sea urchin surveys conducted in Haida, Heiltsuk, Kitasoo and Tsimshian traditional territories, p.57-68. *In:* B.J. Waddell, G.E. Gillespie, and L.C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G.S., Jones, R., Martel, G., Schwarz, C.J., Taylor, C., and Routledge, R. 1998b. Analysis of the 1994 red sea urchin survey conducted in Haida Gwaii, Pacific Fishery Management Area 1, p.3-18. *In:* B.J. Waddell, G.E. Gillespie, and L.C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G.S., Sandoval, W., Schwarz, C.J., Taylor, C., and Routledge, R. 1998c. Analysis of the 1994 red sea urchin surveys conducted in Heiltsuk traditional territory, Pacific Fishery Management Area 7, subareas 18 and 25, p.19-31. *In:* B.J. Waddell, G.E. Gillespie, and L.C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G.S., Scarf, G., Schwarz, C.J., Taylor, C., and Routledge, R. 1998d. Analysis of the 1994 red sea urchin surveys conducted in Aweena K'ola traditional territory, subareas of Pacific Fishery Management Area 12, p.33-56. *In:* B.J. Waddell, G.E. Gillespie, and L.C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G.S., and Schwarz, C.J. 1998. Survey protocol considerations for 1995 red sea urchin surveys, p.69-81. *In*: B.J. Waddell, G.E. Gillespie, and L.C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Kalvass, P. 1992. The Northern California commercial sea urchin fishery – a case study. *In*: The management and enhancement of sea urchins and other kelp bed resources: a Pacific Rim perspective. California Sea Grant College, Report No. T-CSGCP-028.

Kato, S., and Schroeter, S.C. 1985. Biology of the red sea urchin, *Strongylocentrotus franciscanus*, and its fishery in California. Mar. Fish. Rev. 47(3): 1-20.

Sloan, N.A., Lauridsen, C.P., and Harbo, R.M. 1987. Recruitment characteristics of the commercially harvested red sea urchin *Strongylocentrotus franciscanus* in southern British Columbia, Canada. Fish. Res. 5: 55-69.

Systat 10. 2000. SPSS Inc. 233 South Wicker Drive, Chicago, IL. USA. 60606-6307. http://www.systat.com.

Tegner, M.J., and Dayton, P.K. 1981. Population structure, recruitment and mortality of two sea urchins (*Strongylocentrotus franciscanus* and *S. purpuratus*) in a kelp forest. Mar. Ecol. Prog. Ser. 5: 255-268.

Tzotzos, D., Atkins, M., and Campbell, A. 2006. Survey of red sea urchin populations at Price Island, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2757: 21 p.

Tzotzos, D., Campbell, A., and Bureau, D. 2003a. Survey of red sea urchin populations in the Deserters Group area, Queen Charlotte Strait, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2628: 16 p.

Tzotzos, D., Campbell, A., and Bureau, D. 2003b. Survey of red sea urchin populations in the Tofino area, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2630: 18 p.

Tzotzos, D., Campbell, A., and Norgard, T. 2003c. Survey of red sea urchin populations in Laredo Channel, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2629: 20 p.

Tzotzos, D., Campbell, A., and Hajas, W.C. 2003d. Survey of red sea urchin populations in the Becher Bay area, Southern Vancouver Island, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2631: 15 p.

Table 1. Summary of transects surveyed during the August 7 - Sept 1, 2004 red sea urchin (RSU) population survey off Campania Island (PFM sub-area 6-10). Density in number per meter squared and biomass in grams per meter squared. Depths have been corrected to chart datum. Exposure: 4 = moderate exposure, 8 = high exposure. Check marks (✓) indicate transect lying within a known commercial RSU bed.

Transect	Latitude	Longitude	Depth (m)		Exposure	Time		Total Time	Transect	Number	Number RSU	RSU	RSU	In
			Minimum	Maximum		Start	End	(minutes)	Length(m)	Quadrats	Counted	Density	Biomass	Bed
1	53 08.014	129 33.713	-1.31	10.18	8	10:38	10:58	20	57	29	6	0.21	92.22	
2	53 07.178	129 33.013	-0.70	13.90	4	11:39	11:55	16	39	20	9	0.45	59.41	
3	53 07.627	129 32.785	-0.64	12.16	8	12:17	12:38	21	37	19	23	1.21	449.12	
4	53 06.660	129 33.075	-0.37	10.30	8	12:50	13:06	16	67	34	0	0.00	0.00	✓
5	53 05.995	129 31.922	-0.61	10.09	8	15:29	16:06	37	57	29	71	2.45	904.30	✓
6	53 06.470	129 31.079	-1.13	6.68	8	17:01	17:30	29	47	24	76	3.17	1140.78	✓
7	53 05.178	129 30.624	0.46	10.12	8	11:08	11:34	26	57	29	37	1.28	363.21	✓
8	53 06.058	129 30.790	-1.07	3.81	4	09:38	09:50	12	31	16	0	0.00	0.00	
9	53 06.439	129 30.680	-0.61	10.33	4	09:09	09:20	11	41	21	0	0.00	0.00	
10	53 05.870	129 30.246	-1.49	9.14	4	10:07	10:18	11	23	12	0	0.00	0.00	
11	53 04.652	129 29.503	3.81	9.91	8	13:29	13:44	15	33	17	2	0.12	14.38	✓
12	53 04.131	129 27.913	0.52	9.72	8	14:35	14:57	22	21	11	38	3.45	1372.52	✓
13	53 03.306	129 28.163	1.40	9.45	8	15:24	15:50	26	25	13	49	3.77	1094.44	✓
14	53 03.032	129 27.117	-0.12	7.28	8	09:49	10:12	23	151	76	1	0.01	1.58	✓
21	53 02.114	129 26.160	-1.71	6.22	8	12:07	12:19	12	143	72	0	0.00	0.00	✓
22	53 02.062	129 28.352	0.52	9.14	8	10:40	11:10	30	29	15	69	4.60	1816.35	
23	53 01.552	129 26.146	1.49	7.50	8	14:41	15:12	31	73	37	76	2.05	452.41	✓
24	53 01.082	129 26.007	0.82	6.86	8	16:01	16:27	26	69	35	98	2.80	772.78	✓
25	53 00.509	129 25.521	2.47	8.81	8	11:07	11:58	51	73	37	147	3.97	1239.58	✓
28	52 58.851	129 23.233	3.05	8.17	8	13:11	14:52	101	37	18	34	1.89	677.48	✓
29	52 58.632	129 22.849	-1.80	8.05	8	12:21	12:56	35	45	23	141	6.13	1911.87	✓
30	52 58.151	129 21.490	0.12	6.00	8	11:27	11:49	22	59	30	53	1.77	852.91	✓
31	52 57.825	129 21.410	1.28	10.97	8	11:00	11:16	16	25	13	59	4.54	984.07	✓
32	52 57.987	129 20.786	aborted		8	10:45	10:48	3	3	2	0	0.00	0.00	
33	52 57.683	129 19.114	0.85	8.26	8	09:43	10:07	24	47	24	70	2.92	912.31	✓
34	52 57.522	129 18.478	-0.34	4.69	8	15:52	16:08	16	15	8	97	12.13	4944.39	✓
41	52 57.864	129 18.276	-0.27	7.01	8	15:29	15:38	9	17	9	25	2.78	983.37	✓
42	52 58.236	129 17.932	-0.03	4.24	8	15:03	15:15	12	23	12	39	3.25	1506.42	✓
43	52 58.594	129 17.848	0.43	7.77	8	13:07	13:28	21	27	14	77	5.50	1650.70	✓
44	52 58.919	129 18.039	-0.21	8.20	8	12:44	12:53	9	17	9	2	0.22	189.81	✓
45	52 59.360	129 18.205	-0.70	5.30	8	12:20	12:31	11	13	7	29	4.14	1239.64	✓
46	52 59.747	129 18.253	3.23	8.56	8	11:56	12:03	7	13	7	7	1.00	519.61	✓

continued next page

Table 1. continued

Transect	Latitude	Longitude	Depth (m)		Exposure	Time		Total Time	Transect	Number	Number RSU	RSU	RSU	In
			Minimum	Maximum		Start	End	(minutes)	Length(m)	Quadrats	Counted	Density	Biomass	Bed
47	53 00.080	129 18.386	0.82	9.17	8	11:41	11:47	6	13	7	3	0.43	22.71	✓
48	53 00.483	129 18.375	0.58	9.81	8	11:24	11:29	5	15	8	12	1.50	598.62	✓
49	53 00.903	129 18.510	0.30	9.36	8	11:00	11:11	11	19	10	63	6.30	2010.32	✓
50	53 01.290	129 18.497	1.55	7.41	8	12:58	13:04	6	11	6	24	4.00	1642.50	✓
51	53 01.721	129 18.459	1.22	7.13	8	12:37	12:45	8	15	8	11	1.38	818.85	✓
52	53 02.088	129 18.616	-0.27	6.68	8	12:12	12:25	13	31	16	73	4.56	1593.15	✓
53	53 02.580	129 18.956	0.24	7.71	8	11:50	11:57	7	11	6	35	5.83	2263.43	✓
54	53 02.878	129 18.988	-0.27	3.44	8	11:19	11:37	18	29	15	110	7.33	1615.50	✓
61	53 04.485	129 12.560	-0.91	10.94	8	09:24	09:45	21	35	18	59	3.28	883.14	✓
62	53 03.988	129 13.806	-0.18	10.82	8	10:14	10:32	18	35	18	28	1.56	567.52	
63	53 02.727	129 12.979	-1.43	7.07	8	14:54	14:59	5	11	6	17	2.83	1015.57	✓
64	53 03.128	129 12.120	0.27	7.22	8	15:18	15:26	8	17	9	22	2.44	1083.96	✓
65	53 03.796	129 11.970	1.13	3.84	8	15:26	15:29	3	5	3	13	4.33	1051.23	✓
66	53 04.263	129 11.751	0.58	6.55	8	15:48	15:56	8	13	7	26	3.71	1679.82	
67	53 03.717	129 10.695	-0.94	7.47	8	14:54	15:07	13	21	11	51	4.64	1197.03	✓
68	53 02.925	129 10.506	-1.80	7.32	8	14:30	14:37	7	15	8	13	1.63	686.34	
69	53 02.621	129 10.932	-1.58	4.18	8	14:03	14:14	11	13	7	40	5.71	1197.40	✓
70	53 02.189	129 10.975	-1.31	6.61	8	13:38	13:46	8	15	8	19	2.38	960.11	
71	53 01.328	129 11.748	-0.49	7.80	8	12:26	12:58	32	31	16	136	8.50	3445.53	
72	53 00.546	129 11.967	-1.65	8.72	8	11:26	11:45	19	23	12	68	5.67	1812.80	
73	52 59.515	129 12.042	0.61	9.57	8	10:42	11:04	22	23	12	79	6.58	2110.61	
74	52 58.656	129 11.836	0.12	7.80	8	15:45	16:03	18	25	13	86	6.62	1564.88	✓
81	52 58.113	129 11.984	0.21	8.29	8	15:11	15:24	13	17	9	56	6.22	1817.68	✓
82	52 57.579	129 11.955	-1.07	7.28	8	14:36	14:57	21	19	10	42	4.20	711.73	
83	52 57.171	129 11.934	-2.01	7.68	8	14:06	14:22	16	13	7	50	7.14	2089.93	
84	52 56.803	129 11.655	-0.06	8.38	8	13:15	13:49	34	27	14	206	14.71	2771.21	✓
85	52 56.431	129 11.253	-1.04	4.33	8	11:19	12:23	64	53	27	255	9.44	2097.96	✓
86	52 55.910	129 11.631	-0.03	7.10	8	09:59	10:33	34	29	15	83	5.53	1738.16	✓
87	52 55.494	129 11.516	-1.62	8.53	8	14:32	14:57	25	23	12	54	4.50	1209.88	
88	52 55.783	129 10.529	0.21	7.01	8	09:15	09:44	29	29	15	127	8.47	1597.05	✓
89	52 55.143	129 09.926	0.70	7.56	8	13:49	14:13	24	29	15	83	5.53	1183.74	✓
90	52 54.764	129 10.081	-2.65	7.65	8	13:19	13:33	14	15	8	45	5.63	1375.84	
91	52 54.321	129 09.401	-0.67	2.16	8	11:35	11:54	19	27	14	48	3.43	779.89	✓
92	52 53.903	129 09.092	-0.12	2.10	8	10:59	11:17	18	13	7	19	2.71	526.97	✓
93	52 52.774	129 7.595	-0.12	8.60	8	10:24	10:45	21	29	15	56	3.73	909.06	✓
94	52 52.373	129 8.104	0.24	9.33	8	9:48	10:15	27	23	12	38	3.17	819.22	✓

Table 2. Mean number of red sea urchins (RSU), mean substrate category, and percent cover by algae for each depth category surveyed during the 2004 survey conducted in the area of Campania Island. Depths have been corrected to chart datum. Substrate categories: 1 = rock, 2 = sand/shell, 3 = mud. Canopy = tall, shading, surface-reaching algae. Understorey = 30cm to 2m in height. Turf = 5cm to 30cm in height. Encrusting = species forming a thin, crustose layer on rocks.

Depth Range (m)	Number of RSU		Number Of Quadrats	Mean Substrate Category	Mean Percent Cover by Algae			
	Total	Mean per Quadrat			Canopy	Understorey	Turf	Encrusting
<0.0 m	165	3.1	54	1.02	10.7	58.8	24.1	28.0
0.0 - <2.5 m	1488	6.2	240	1.12	7.0	34.4	9.9	42.7
2.5 - <5.0 m	1144	3.7	312	1.22	7.4	21.9	4.0	43.3
5.0 - <7.5 m	473	1.6	304	1.44	0.5	20.3	1.8	33.9
7.5 - <10.0 m	203	1.3	156	1.20	0.0	25.9	3.2	46.2
10.0 - <12.5 m	12	0.3	48	1.63	0.0	38.9	4.2	16.9
≥12.5 m	0	0.0	10	1.00	0.0	40.0	0.0	80.0

Table 3. Number of red sea urchins measured and percent of urchins ≤50 mm TD and ≥90 mm TD surveyed during the 2004 population survey in the area of Campania Island. R_T = percent of all red sea urchins that were ≤50 mm TD. R_S = percent of sublegal urchins that were ≤50 mm TD.

Transects Used	Test Diameter (mm)			Numbers Measured			% Total Measured		% Sublegals
	Mean	Minimum	Maximum	≤50 mm TD	≥90 mm TD	Total	≤50 mm (R_T)	≥90 mm	≤50 mm (R_S)
Within Beds	87.3	6	168	359	1400	2719	13.2	51.5	27.2
Outside Beds	94.3	8	159	57	429	666	8.6	64.4	24.1
All	88.7	6	168	416	1829	3385	12.3	54.0	26.7

Table 4. Mean density and biomass estimates of red sea urchins by size (test diameter, TD), within and outside of commercial beds, for the 2004 survey in the area of Campania Island. Estimates are for transects within red sea urchin beds recorded between 1997 and 2000, for transects outside the beds, and for all transects combined. Values in brackets are ± S.E..

Transects Surveyed	Number Of Transects	Sum of Transect Lengths (m)	Mean Density (no./m^2) by TD			Mean Biomass (g/m^2) by TD		
			≤50 mm	≥90 mm	All Sizes	≤50 mm	≥90 mm	All Sizes
Within Beds	50	1704	0.42 (0.09)	1.64 (0.26)	3.20 (0.54)	10.19 (2.23)	731.25 (115.53)	909.81 (144.94)
Outside Beds	18	482	0.23 (0.07)	1.71 (0.48)	2.65 (0.71)	6.07 (1.79)	787.69 (236.64)	891.02 (259.21)
Total	68	2186	0.38 (0.07)	1.65 (0.23)	3.08 (0.45)	9.28 (1.76)	743.69 (103.88)	905.67 (125.63)

Table 5. Kruskal-Wallace test results for comparing mean densities of red sea urchins by size groups between inside and outside commercial bed areas for the 2004 survey in the area of Campania Island.

PFM sub-area		P-values		
		≤50 mm	≥90 mm	All Sizes
6-10	In vs. Out	0.129	0.884	0.500

Table 6. Mean density estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2004 survey in the area of Campania Island. Values in brackets area ± S.E..

Depth Range (m)	Mean Density (number/m^2) by test diameter								
	≤50 mm			≥90 mm			All Sizes		
	In	Out	Total	In	Out	Total	In	Out	Total
<0.0 m	0.60 (0.38)	0.09 (0.06)	0.39 (0.24)	1.96 (1.16)	0.86 (0.47)	1.51 (0.74)	4.26 (2.62)	1.35 (0.76)	3.08 (1.67)
0.0– <2.5 m	0.93 (0.24)	0.66 (0.24)	0.89 (0.21)	2.67 (0.43)	6.14 (1.54)	3.13 (0.48)	5.77 (1.09)	8.65 (2.29)	6.15 (1.02)
2.5 – <5.0 m	0.43 (0.12)	0.39 (0.18)	0.43 (0.11)	1.95 (0.43)	1.76 (0.69)	1.92 (0.38)	3.70 (0.80)	3.29 (1.28)	3.64 (0.69)
5.0 – <7.5 m	0.09 (0.03)	0.18 (0.08)	0.11 (0.03)	0.83 (0.24)	1.28 (0.54)	0.92 (0.23)	1.39 (0.40)	2.14 (0.76)	1.54 (0.37)
7.5 – <10.0 m	0.16 (0.08)	0.07 (0.05)	0.13 (0.06)	0.74 (0.22)	0.97 (0.47)	0.80 (0.20)	1.27 (0.38)	1.36 (0.64)	1.29 (0.32)
10.0 – <12.5 m	0.00	0.00	0.00	0.27 (0.29)	0.21	0.23 (0.18)	0.33 (0.37)	0.21	0.25 (0.20)
≥12.5 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Biomass estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2002 survey in the area of Campania Island. Values in brackets area ± S.E.

Depth Range (m)	Mean Biomass (g/m^2) by test diameter								
	≤50 mm			≥90 mm			All Sizes		
	In	Out	Total	In	Out	Total	In	Out	Total
<0.0 m	15.44 (10.48)	4.31 (2.82)	10.92 (6.63)	763.17 (434.33)	334.13 (190.27)	588.90 (279.90)	1033.61 (604.86)	392.22 (223.14)	773.09 (387.32)
1.0– <2.5 m	20.40 (5.45)	14.94 (4.60)	19.68 (4.74)	1172.58 (179.48)	2984.37 (861.41)	1411.91 (226.48)	1510.03 (241.14)	3230.29 (937.82)	1737.27 (270.55)
2.5 – <5.0 m	11.73 (3.42)	10.61 (5.00)	11.55 (2.96)	882.47 (200.21)	804.30 (320.27)	870.10 (174.48)	1092.29 (239.43)	984.25 (379.57)	1075.19 (208.35)
5.0 – <7.5 m	2.16 (0.82)	5.86 (2.93)	2.88 (0.95)	377.82 (112.28)	529.20 (229.12)	407.33 (103.77)	449.78 (131.03)	628.10 (248.98)	484.53 (119.78)
7.5 – <10.0 m	4.51 (2.99)	1.57 (1.23)	3.70 (2.16)	357.33 (104.81)	470.43 (225.60)	388.31 (97.35)	411.85 (120.54)	514.67 (242.55)	440.01 (108.93)
10.0 – <12.5 m	0.00	0.00	0.00	94.95 (107.85)	87.22	89.64 (74.01)	106.01 (121.91)	87.22	93.11 (75.89)
≥12.5 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

This page purposely left blank.

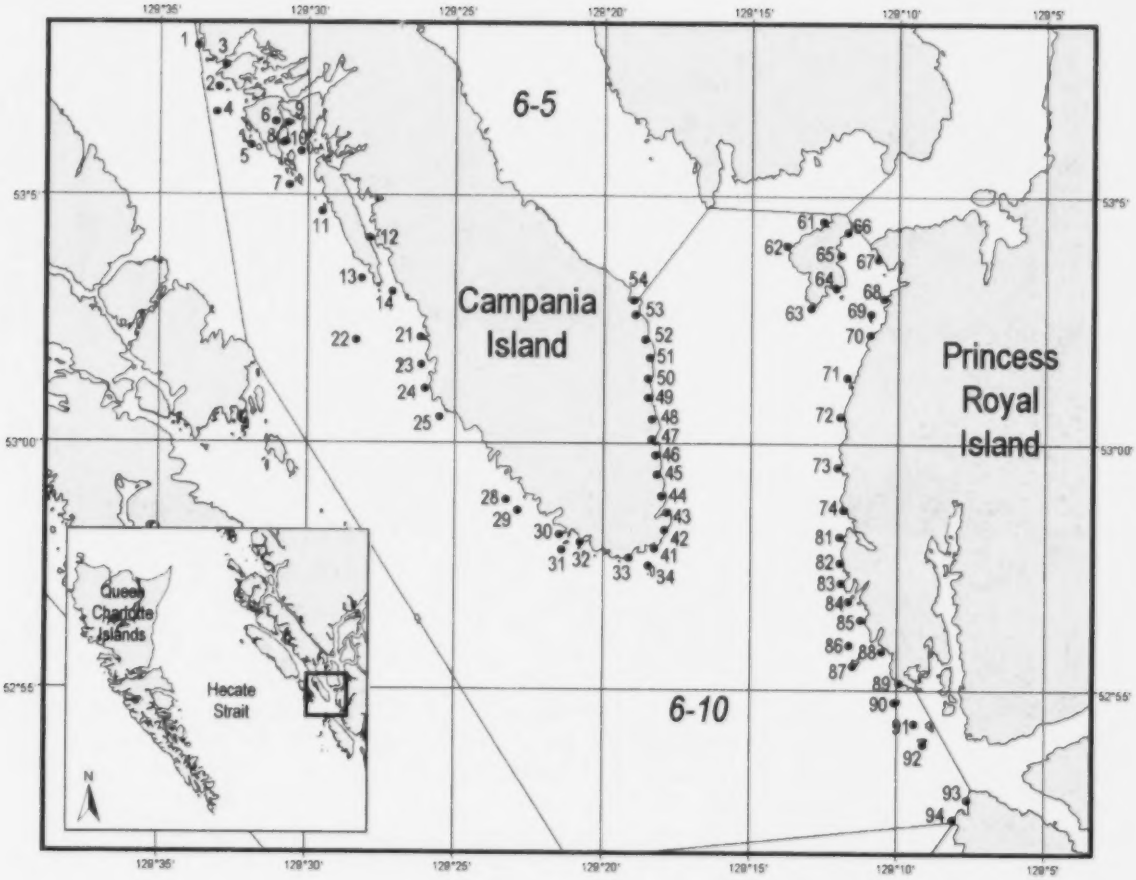

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in the area around Campania Island, 2004. Hyphenated numbers indicate Pacific Fisheries Management sub-areas and other numbers indicate transects. Inset map indicates survey location.

This page purposely left blank.

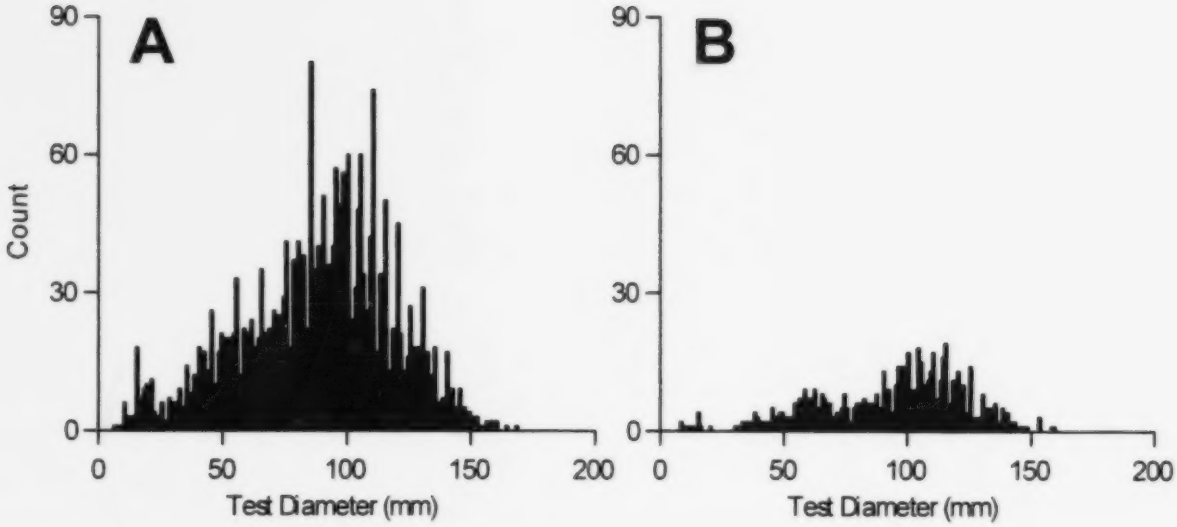

Figure 2. Size frequency distribution of red sea urchins measured (A) inside (n=2719) and (B) outside (n=666) of commercial bed areas during the 2004 survey near Campania Island. n= number of red sea urchins measured for test diameter.